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THE INCREASING POLLUTION OF OUR MUNICIPAL WATER-SUPPLIES.

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It seems hardly necessary here to go into a detailed account of the necessity for a pure drinking water. The same is also precluded by the length of the paper which I have prepared. Certainly no agent is more important to the well-being of the human race—a fluid which constitutes about three-fourths of the human body and animal tissues generally; the universal solvent; the beverage of beverages, essential to the performance of all the vital functions. As vegetation on the earth's surface would be impossible without moisture, so also would the human body soon cease in its vital phenomena without an adequate supply of hydrogen and oxygen associated in their proper proportions. While it is essential for the performance of these offices it is equally necessary in removing the results of functional activity—namely, waste tissue products. This brings us to the consideration of *purity*. As water can hold in solution only a certain amount of solids, its solvent power in the system—one of its chief effects—is necessarily impaired when it is charged with compounds, organic and inorganic, and the waste products which it should take up and carry off through the emunctories, accumulate and exert their deleterious effects, both mechanical and chemical.

While the system may combat for a time a certain excess of mineral impurities, they sooner or later make their effects manifest upon the excretory organs, the kidneys especially. Just how much of a rôle the lime salts carried by water have

in the causation of the pipe-stem arteries of advancing life, in calcification and atheroma, is not fully established, but the inference seems justifiable that such influence is considerable. These changes conform to the pathological histology of contracted and granular kidney the etiology of which is as yet obscure, to the general condition of the circulatory system known as arterio-capillary fibrosis. It being through the circulatory system that water is carried through the body, and constituting, as it does, about nine-tenths of the weight of the blood and fluids therein contained, naturally it is in the arterial and capillary systems that the effects of impurities thus carried are apt to be first noticed. Probably the chief primary effect is simple irritation, as this would explain best the microscopical changes characterising arterio-capillary fibrosis.

So much with reference to the general circulatory effect of the *inorganic* impurities upon the system. The chief feature of impure water which I wish to discuss, pertains to its *organic* constituents, not chemical alone but biological; to the living pathogenic microorganisms which it is liable to contain. I do not wish to enter into the effects of albuminoid ammonia and other chemical products indicating serious pollution of a water-supply, but rather prefer at this time to confine myself to the subject of the bacterial contamination, introducing, however, a few general considerations.

Undoubtedly the contamination of our municipal water-supplies is at the present time reaching a degree which should occasion great alarm, and no one who has given the subject thought can fail to be impressed with the importance of a consideration of the ways and means of suppressing the evil. It is equally true that more ailments and diseases arise from the use of impure water than from any other known cause, and yet most people are conspicuously careless as to the quality of water which they drink. In many cases this is the result of ignorance; in others it is due to carelessness.

Thus the subject becomes the most important sanitary topic which we have to consider today, and thus far it has not

received the amount of attention which it merits. The condition referred to is the natural outcome of the rapidly increasing population of our country, without corresponding increase of precaution in the disposition of sewage, which in most instances is allowed to mingle with adjacent waters unaltered. "Even a small amount of sewage entering near the intake to a water-supply is sufficient to destroy the small margin of safety otherwise existing in regard to the water's purity," (Rafter) and hence, as may readily be understood, there are as yet few sanitarily unobjectionable water-supplies in the United States. In many cities the condition of affairs is really alarming, as attested by frequent outbreaks of typhoid fever, or, as is the case in other instances, by the endemic presence of this disease. Among such cities may be mentioned New York, Chicago, Philadelphia, Cincinnati, Pittsburgh, St. Louis, Buffalo, Cleveland, New Orleans, Minneapolis, Milwaukee and Detroit, besides many smaller towns. In all of these and other parts we have frequent controversies concerning the impurity of the local water-supply, and discussions and agitations as to the most available means of improving the condition. In some of the cities active steps have been taken, or are being taken, to abolish or mitigate impending dangers. In others, too much politics and want of proper sense of duty on the part of the authorities lead to a continuance of the deplorable state of affairs.

To give an impression of the kind of water furnished to the inhabitants in some of our large cities the following quotation may be of service :

"A sad state of affairs exists in Brooklyn. The source of the water-supply is inadequate and the daily papers are full of complaint. A lay contemporary, who has taken pains to investigate the matter, speaks as follows : 'From stagnant ponds, vile and reeking, filled with dirt and decaying and fermenting vegetation, covered with slimy decomposing masses, swarming with bugs, insects and fish, full of white snaky threads, receiving gas-house refuse and house drainage, and covered with green scum, we get the water we

drink.' No wonder the citizens howl, for this is a shameful description of the water resources of a city that is soon to wed New York."

Naturally, sewage constitutes the most important source of pollution of our municipal water-supplies. Could some means of its treatment on a large scale (other than the sewage farm system), as, for example, electrolysis, be devised, much would be done toward solution of that much vexed question, the purification of our municipal waters. As in preventative medicine, prophylaxis is the first law of sanitary science today.

Chicago discharges about 50,000 cubic feet of sewage per minute into Lake Michigan, through its river, the Chicago. London, England, has 200,000,000 gallons of sewage per day. "Erie, Pa., has 5,000,000 gallons daily, and Toledo, O., 8,000,000. Cleveland, O., in 1893, besides her sewage, emptied 15,693 cubic yards of night soil into Lake Erie and 7,800 tons of garbage. Dunkirk has thirteen miles of sewerage." (Krauss.)

From these figures an impression may be formed as to the amount of sewage and refuse which any town has to dispose of, and we may more fully realise the enormity of this influence in contaminating a body of water naturally pure. This, to reiterate, is one of the worst penalties of increasing population and the aggregation of the masses.

A timely contribution on the subject of sewage was that of Mr. E. O. Jordan, of the Massachusetts State Board of Health, (1889-'90). Mr. Jordan reports on and carefully describes twelve species of bacilli, most of them previously unknown, isolated at the experimental sewage station of Lawrence, Mass., and further adds an important report on nitrification and the organisms concerned in the process.

The results of Mr. Jordan's examination of the sewage of Lawrence, Mass., gave an average of 708,000 living bacteria per cubic centimeter, his highest result being 3,963,000 per cubic centimeter. He obtained far greater numbers during the summer months than at other times. Laws and Andrewes, from whose report I take the liberty to quote, giving them due

credit, found that the number of bacteria in London sewage is considerably higher than the above. Determinations of the number of microorganisms in the sewage of the King's Scholar's Pond sewer, London, in November and December, 1891, showed 2,618,000 and 3,179,000 respectively. In their report to the London County Council the last-named observers state that "in perfectly fresh sewage from St. Bartholomew's hospital on January 26, 1894, at 10.30 A. M., from which cultivations were made immediately, without allowing any time for the multiplication of the microorganisms, we found on an average 2,781,650 bacteria per cubic centimeter. Two agar-agar plates, inoculated each with 1 cubic centimeter of the sewage diluted 10,000 times and incubated at 22° C., yielded respectively 216 and 330 colonies." Six similar plates, inoculated each with 1 cubic centimeter of the sewage diluted 100,000 times, yielded respectively 21, 39, 26, 27, 28 and 29 colonies. The same sewage, however, after being kept for three days in a stoppered bottle, showed an enormous increase in bacteria; a similar plate, inoculated with 1 cubic centimeter of the sewage diluted 100,000 times, yielded 388 colonies, representing 33,800,000 bacteria per cubic centimeter.

From the Fleet sewer on Snow-hill, London, the results were somewhat higher. The sewage was taken on March 2, 1894, at 11.30 A. M., and cultivations were made immediately. Three agar-agar plates gave 40, 28 and 34 colonies, yielding an average of 3,400,000 bacteria per cubic centimeter. With this sewage also further experiments were made to ascertain what proportion of the bacteria present would grow at a temperature of 37° C., or with the addition of .05 per cent. carbolic acid, or under the influence of both these conditions combined. Two agar-agar plates, inoculated each with a cubic centimeter of the sewage diluted 10,000 times, with the addition of .05 per cent. carbolic acid, and incubated at 37° C., yielded respectively 59 and 38 colonies, giving an average of 485,000 organisms which could grow under these unfavorable conditions.

"These results indicate that a temperature of 37° C. inhibited the growth of 73.4 per cent. of the total number of organisms present in this sewage, while the addition of .05 per cent. carbolic acid inhibited the growth of 44.2 per cent. of the total number; the combination of .05 per cent. carbolic acid, with a temperature of 37° C., inhibited the growth of no less than 85.8 per cent. of the bacteria present.

"Two agar-agar plates, containing each 1 cubic centimeter of the sewage diluted 100,000 times, but with the addition of .05 per cent. carbolic acid, yielded, when incubated at 22°, 11 and 8 colonies respectively, equal to 950,000 organisms per cubic centimeter of sewage able to grow in the presence of this amount of carbolic acid, *i. e.*, 50 per cent. were inhibited in their growth.

"With regard to the total number of organisms present in sewage, the highest results were obtained from a sample taken at the Crossness outfall, London, England, at 2.30 P. M., of July 10, 1894. Six agar-agar plates were made, each containing 1 cubic centimeter of the sewage diluted 100,000 times, and they were incubated at 22° C. They yielded respectively 124, 127, 105, 119, 110 and 88 colonies, or an average of 11,216,666 microorganisms per cubic centimeter of sewage." (Laws and Andrewes.)

Can one conceive how even great dilution of such sewage in water can render it free from danger?

"The sewage collected from the fever hospital at Homerton, London, on May 23d, at 11 A. M., was examined chiefly for the purpose of discovering the typhoid fever bacillus.

"No less than forty-five colonies resembled, at first sight, *B. coli communis*, but of these less than a dozen responded to the chemical tests (coagulation of milk, formation of gas bubbles in gelatine shake-cultures, and production of indol in broth,) which are relied on to distinguish the bacillus from its allies. It was, nevertheless, if we except a certain streptococcus found, the commonest, and certainly the most conspicuous, of the organisms present in this sewage. Those of the forty-five colonies which failed to give some or all of the

three chemical tests must be classed, from their morphological and cultural resemblances, as close allies of *B. coli communis*, a near relative of typhoid, but we are unable to refer them to any described species.

Proteus Zenkeri, a common putrefactive organism, occurred twice. A bacillus allied to *B. pyocyaneus*, of green pus, which we describe as *Bacillus cloacæ fluorescens*, occurred twice.

The following other organisms were found to be present in sewage in numbers varying from 200,000 to 2,500,000 per cubic centimeter: *Bacillus fluorescens stercoralis*, *Bacillus albus putidus*, *Bacillus fluorescens liquefaciens*, *Bacillus cloacæ fluorescens*, *Bacillus mycoides*, *Proteus cloacinus*, *Proteus Zenkeri*, a streptococcus coagulating milk, *Staphylococcus pyogenes citreus*, *Sarcina flava* and its allies, and *Diplococcus albicans tardissimus*. Other bacilli which rapidly liquefy gelatine and produce a green fluorescence, were found in numbers varying from 10,000 to 200,000 per cubic centimeter."

The method employed by Laws and Andrewes in their study of sewage, which was designed to secure an equable admixture of the material with the large amount of diluent required, was as follows: Ten cubic centimeters of the mixed and shaken sewage were diluted to 100 cubic centimeters with recently boiled distilled water in a sterilised and accurately stoppered flask, and thoroughly shaken. Of this dilution 10 cubic centimeters were taken and further diluted to 1,000 cubic centimeters with sterilised distilled water in a second sterile flask, and again well shaken. Of this second dilution (which represents 1 in 1,000) two further dilutions were made in similar manner—one by taking 10 cubic centimeters and diluting to 100 cubic centimeters (giving a dilution of 1 in 10,000), and another by taking 10 cubic centimeters and diluting to 1,000 cubic centimeters, giving a dilution to 1 in 100,000. These extreme degrees of dilution were, of course, rendered necessary by the enormous number of microorganisms present even in fresh sewage. And even with the

extreme dilutions, the gelatine plates used for cultivating the organisms soon became useless, on account of the rapid liquefaction produced by the growth of bacterial colonies.

The disinfection of typhoid excreta is a matter of extreme difficulty, and is, as a rule, very imperfectly carried out even in fever hospitals. It hence results that sewage becomes a very potent agent in the dissemination of this disease and the contamination of water supplied by such sewage the chief cause of typhoid epidemics. Attention to the inquiry which the London investigators carried out was especially directed to the possible occurrence of the *Bacillus typhosus* in London sewage, and every colony which seemed likely to belong to this species was the subject of careful investigation.

It is estimated that even though the typhoid fever bacillus be intimately mixed with the city's sewage from typhoid fever cases direct, there will be only one typhoid fever bacillus in one-tenth of a cubic centimeter of the sewage at the outfall. So numerous were the failures of the above observers in their attempt to find the typhoid bacillus in London sewage they finally became oppressed by a sense of mathematical improbability. The average amount of sewage produced in London, England, is 200,000,000 gallons per day. Calculating that 200 cases of typhoid fever prevailed during the time when the observations were made, it is estimated that the amount of typhoid sewage amounted to one two-hundred-and-fifty-thousandths of the whole. The investigators only found it possible to work on one five-thousandth of a cubic centimeter of sewage.

The chief interest which attaches to the contamination of drinking water by sewage pertains to the possible presence of the typhoid fever bacillus (or virulent colon bacilli, which produce a train of clinical symptoms closely corresponding with those caused by the former organism). Laws and Andrewes have shown that in the drains from a hospital where typhoid fever is prevalent the typhoid fever bacillus may be isolated without difficulty. This had never previously been done. The organism was, furthermore,

found to live in raw sewage, at the ordinary temperature, for two weeks. At a warmer temperature, even after thirty days and in presence of pure cultures of various other organisms, the typhoid bacillus was found alive and active. The colon bacillus was cultivated in sewage through several generations.

From the foregoing deductions it would appear that the fact of the typhoid fever bacillus not being found more often in water supplies is no particular argument against its presence. The better method for demonstrating the presence of the typhoid bacillus in water is by the inoculation of white rats with samples of water placed in beef tea and incubated for twenty-four hours at 40° C. The presence also of a small amount of carbolic acid with the higher temperature will restrict the development of most of the water bacteria, when we will have remaining simply typhoid (or colon bacilli). Such cultures injected into the abdominal cavity of a white rat promptly lead to the development of severe inflammatory symptoms or even death. Without this animal experiment the task of finding the typhoid bacillus in drinking water is often exceedingly difficult; with it it becomes comparatively easy. The new serum test, with which I am myself now experimenting, promises to be an important aid.

[This consists in adding to a hanging drop of a mobile organism a drop of blood (even after it has been dried) from a patient suffering from typhoid fever, any time after the first week. If the organism under consideration be typhoid its motion ceases, the cells becoming agglutinated, when they are seen in clumps or masses in the field of the microscope. If the organism is not typhoid the motion continues. The writer has tried the test upon a number of mobile organisms with the result of convincing himself that the antitoxin of typhoid fever does not act upon other mobile bacteria in the way that it does upon the germ to which it owes its origin.]

Wide variations exist in the total number of microorganisms present in sewage at different times and in different places, as might be predicted. Temperature is one of the

most important factors in determining the rapidity of their reproduction and increase in numbers. Dilution of sewage by rainfalls exerts a marked modifying influence.

A striking difference exists between the organisms found in sewage air and in sewage itself. The molds which predominate in the former are very rarely observed in the latter. Out of the many thousand colonies which arose on numerous plates made from London sewage mold fungi occurred only seven times, and of these seven only one was allied to the common species existing in sewage air. These results coincide with those obtained by Jordan and others.

In showing the influence of locality on the number of bacteria present in different parts of a river the following observations are of value: The water of the Seine at Choisy, before reaching Paris, is found to contain 300 bacteria; at Bercy, 1,200; at St. Denis, after receiving sewer water from the city, 200,000 germs per cubic centimeter (Miquel). Water of the Spree beyond Kopenick, 82,000 bacteria. Two hundred steps below the mouth of the Panke, 940,000; below the mouth of the Panke, 1,800,000 (Koch). Water of the Main river above the city of Würzburg, in the month of February, 520; below the city, 15,500 (Rosenburg). The water of the Thames in the autumn of 1885, in the vicinity of London bridge, two hours after high water, contained 45,000 germs per cubic centimeter; the water of the Lea at Lea bridge, 4,200,000 (Bischoff). The water of the Oder, collected within the limits of the city of Stettin, was found by Link to contain from 5,240 to 15,000 bacteria per cubic centimeter; that of the Limmat, at Zurich, 346 in one specimen and 508 in another (Cramer). The water of the Spree river of Berlin contains 400 bacteria at the Stralauer works.

Adametz (1888) has described 87 species of bacteria obtained by him from water in the vicinity of Vienna; Maschek found 55 different species in the drinking water used at Leitmeritz; and Tils (1890) has described 59 species obtained from the city water used at Freiburg.

The following are the ordinary pathogenic organisms found in water :

Pathogenic Bacilli.—*Bacillus typhi abdominalis* (Eberth, Gaffky), *Bacillus erysipelatos suis* (" *Bacillus murisepticus*," Koch), *Bacillus septicæmiæ hæmorrhagicæ* (" *Bacillus cuniculicida*," Koch), *Proteus vulgaris* (Hauser), *Proteus mirabilis* (Hauser), *Bacillus canalis capsulatus* (Mori), *Bacillus canalis parvus* (Mori), *Spirillum cholera Asiaticæ* (Comma bacillus, Koch), and a group of spirilla closely resembling it ; *Bacillus venenosus* (Vaughan), *Bacillus coli communis* (Escherich), *Bacillus hydrophilus fuscus* (Sanarelli), *Bacillus venenosus brevis* (Vaughan), *Bacillus venenosus invisibilis* (Vaughan), *Bacillus venenosus liquefaciens* (Vaughan).

Pathogenic Micrococci.—*Staphylococcus pyogenes aureus* (Rosenbach), Micrococcus of Heydenreich—" *Micrococcus Biskra*." The former of the two last named germs being the common producer of abscesses, inflammations and phlegmons.

Concerning the probable presence of the *Plasmodium malaria* in drinking water that is charged with vegetable matter from low marshy districts, we have an important suggestion from the lower Mississippi Valley. So extensively did this disease prevail in the large tract—the delta—between the Mississippi and Yazoo rivers, population of the region seemed for a time to be impossible. Now the use of artesian wells there has brought a wonderful change. The residents of the delta used to drink the water from small surface streams, shallow wells and sluggish bayous. As a result of the use of water free from such surface contamination the region has been robbed of many of its terrors and has proved to be exceedingly healthy. For hundreds of years the Roman Campagna was the home of the deadly fever called Roman fever. The water-supply of the "Eternal City" was very poor and the fever made great ravages ; but since improvement in the water-supply the death-rate of Rome is lower than that of Naples, Florence, Turin and Milan, and there occurs scarcely a death in Rome from malarial disease con-

tracted within the city. While we in the North do not have the extensive swamps of the Mississippi region, still there is in the above an important lesson for us.

The following table may here be of interest :

Name of City.	Total Water Revenue.	Annual Receipts from Mineral Water.	Average Daily Consumption in Gallons.	Revenue per Million Gals.	Meter rate per 1000 Gals.
New York . .	\$3,457,347.04	\$1,520,897.20	154,000,000	\$ 61.50	.131 $\frac{1}{3}$
Chicago . . .	2,592,111.67	795,292.67	174,000,000	40.81	.08-.10
Philadelphia .	2,634,481.52	125,705.73	163,800,000	44.06	.08
Brooklyn . . .	1,486,003.38	295,087.57	58,054,000	70.12	.10-.15
St. Louis . . .	1,235,933.30	555,850.50	44,162,000	76.67	.10-.30
Boston	1,838,494.30	587,850.50	46,740,000	107.76	.16-.18 $\frac{2}{3}$
Baltimore . .	869,777.67	159,459.86	47,000,000	50.70	.06
Cincinnati . .	988,053.90	188,034.05	42,119,000	64.27	.09-.15
Cleveland . .	598,433.50	258,885.09	36,443,000	44.98	.05 $\frac{1}{3}$

Thus it will be seen that the subject of the water-supply in every large city is one that involves great financial considerations, and it would appear consistent to expend a little more (or, in some instances, perhaps less,) and improve the *quality* of the supply.

As I have discussed at length the subject of the purification of water for drinking purposes, in the January, 1897, number of *The Chautauquan*, I will not touch further upon it here.